

A New CEMP-s RR Lyrae Star

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ABSTRACT

We show that SDSS J170733.93+585059.7 (hereafter SDSS J1707+58), previously identified by Aoki and collaborators as a carbon-enhanced metal-poor star (with s-process-element enhancements; CEMP-s), on the assumption that it is a main-sequence turn-off star, is the RR Lyrae star VIII-14 identified by the Lick Astrograph Survey. Revised abundances for SDSS J1707+58 are $[\text{Fe}/\text{H}] = -2.92$, $[\text{C}/\text{Fe}] = +2.79$, and $[\text{Ba}/\text{Fe}] = +2.83$. It is thus one of the most metal-poor RR Lyrae stars known, and has more extreme $[\text{C}/\text{Fe}]$ and $[\text{Ba}/\text{Fe}]$ than the only other RR Lyrae star known to have a CEMP-s spectrum (TY Gru). Both stars are Oosterhoff II stars with prograde kinematics, in contrast to stars with $[\text{C}/\text{Fe}] < +0.7$, such as KP Cyg and UY CrB, which are disk stars. Twelve other RR Lyrae stars with $[\text{C}/\text{Fe}] \geq +0.7$ are presented as CEMP candidates for further study.

Subject headings: stars: horizontal branch, stars: abundances, Galaxy: structure

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1. Introduction

Stars with strong carbon features, such as molecular CH and C₂, in their spectra are referred to as carbon stars; Wallerstein & Knapp (1998) provide a detailed review of carbon-star properties. High-velocity CH (strong G-band) stars were first noticed by Keenan (1942). Bond (1974) observed a metal-weak subgroup of these stars whose spectra exhibited overabundant CH and s-process elements. He called them “Population II carbon stars”, and showed that they had a wide range in luminosities. CH stars can be found among the red giants in the globular cluster ω Cen, although they are rare in other globulars. Stars with these characteristics are now known to be a very heterogeneous group.

Beers & Christlieb (2005) defined metal-poor stars as those with $[\text{Fe}/\text{H}] < -1.0$, and carbon-enhanced metal-poor stars with enhanced s-process elements (referred to by these authors as CEMP-s stars) as those with $[\text{C}/\text{Fe}] > +1.0$ and $[\text{Ba}/\text{Fe}] > +1.0$. More recently, Suda et al. (2011) have considered CEMP-s stars to be those that have $[\text{Fe}/\text{H}] \leq -2.5$, $[\text{C}/\text{Fe}] \geq +0.7$, and $[\text{Ba}/\text{Fe}] \geq +0.5$ (explicitly including very low metallicity in their definition), although large numbers of more metal-rich CEMP-s stars satisfying the original Beers & Christlieb criteria certainly exist, and indeed represent the majority of such objects.

Wallerstein et al. (2009), in an ongoing survey of carbon abundances of RR Lyrae stars, have shown that the two metal-rich RR Lyrae stars, KP Cyg and UY CrB, have $[\text{C}/\text{Fe}]$ of +0.52 and +0.65, respectively. KP Cyg and UY CrB have long periods for such metal-rich stars, and Andrievsky et al. (2010) suggest that they are instead short-period Cepheids. Additionally, Wallerstein & Huang (2010) have given carbon abundances for 24 RR Lyrae stars – all had $[\text{C}/\text{Fe}] \leq +0.15$; they concluded that higher $[\text{C}/\text{Fe}]$ were found in more metal-rich stars.

The only RR Lyrae star now known to be a CEMP-s star is TY Gru, a Bailey type ab star with a period of 0.57 days, found by Preston et al. (2006) among the metal-poor candidates identified during the course of the HK Survey of Beers and collaborators (CS 22881-071; Beers et al. 1992). Preston et al. showed that TY Gru has $[\text{Fe}/\text{H}] = -2.0$, $[\text{C}/\text{Fe}] = +0.9$, $[\text{Ba}/\text{Fe}] = +1.2$, as well as enhancements among other s-process-element abundances. Stars with such abundances have been shown to be binaries in which mass transfer has occurred from an AGB companion at an earlier evolutionary stage. TY Gru, however, has a variable light and velocity curve (Blazhko effect), and its binary nature has yet to be shown, despite strenuous efforts by Preston (2009).

Measurements of carbon abundances among metal-poor stars (e.g., Beers & Christlieb 2005, and references therein; Aoki et al. 2012) have established the increasing frequency of stars with large $[\text{C}/\text{Fe}]$ with decreasing $[\text{Fe}/\text{H}]$. Carollo et al. (2012) have determined the

[C/Fe] abundance ratio for over 30,000 calibration stars from the Sloan Digital Sky Survey (SDSS; York et al. 2000). They confirm the increasing frequency of stars with $[C/Fe] > +0.7$ (CEMP stars) with decreasing $[Fe/H]$, and also with increasing distance ($|Z|$) from the Galactic plane. The frequency of CEMP stars kinematically associated with the outer halo was also shown by these authors to be roughly twice that of such stars kinematically associated with the inner halo. For further background, see Carollo et al. (2010). One of the CEMP stars in their sample is SDSS J1707+58. Aoki et al. (2008) identified it as a CEMP star among a number of presumed main-sequence turn-off stars from the SDSS/SEGUE sample, interpreting its observed rapid variations in radial velocity as due to motion within a tight binary system.

In this paper, we show that SDSS J1797+58 is the RR Lyrae star VIII-14, identified in the spectroscopic study of RR Lyrae stars of Suntzeff et al. (1991), who assigned an $[Fe/H] = -2.5$, and noted that it had a strong CH G-band. Aoki et al. (2008) estimated an $[Fe/H] = -2.52$, along with $[C/Fe] = +2.1$ and $[Ba/Fe] = +3.40$; we revise these values on the basis of its new identification as an RR Lyrae. The presence of carbon enhancements in RR Lyrae stars is of particular interest, since they are excellent population tracers in the Galaxy. In this paper we compare SDSS J1707+58 with the other carbon-enhanced variables TY Gru, KP Cyg, and UY CrB. We also discuss how additional samples of such stars might be found.

2. Photometry, Radial Velocities, and Ephemeris of SDSS J1707+58

The RR Lyrae star VIII-14 (Suntzeff et al. 1991) was originally discovered in a survey with the Lick Astrograph (Kinman et al. 1984); the star is in field VIII¹, and has coordinates $17^h 07^m 33.^s93 +58^\circ 50' 59.''9$ (J2000) and Galactic coordinates $l = 87.^\circ69$, $b = +36.^\circ29$. Its proper motion, given in SDSS DR8 (Adelman-McCarthy et al. 2011), is $\mu_\alpha = -4 \pm 3$ mas y^{-1} and $\mu_\delta = +3 \pm 3$ mas y^{-1} . We derive photographic B magnitudes from 42 exposures on 103-aO emulsion (May 1964 to August 1965; blue open circles in Fig 1c), and from 32 exposures on II-aO emulsion (June 1976 to April 1985; red filled circles in Fig 1c), using the Lick Carnegie Astrograph². The exposures on the latter plates are longer, and the magnitudes derived from them should be more accurate. We derive the B magnitudes of the comparison stars from their SDSS *ugr* magnitudes, using the transformations of Lupton (2005). Photoelectric *BV* magnitudes of VIII-14 were obtained with the KPNO 1.3-m telescope³ between 1979 March

¹ A paper describing the stars in this field is currently being prepared for publication.

²For further details see Kinman (1965).

³ For more details see Sec. 3.1 of Kinman et al. (1994).

25 UT and 1986 June 10 UT (black filled circles in Fig 1b and 1c). The radial velocities are taken from Table 3 of Aoki et al. (2008), and phased according to the method of Liu (1991), assuming a V amplitude of 0.61 mag. This yields a γ -velocity of $+18.5 \text{ km s}^{-1}$, and a JD hel (at maximum) at 2,454,141.503. From this we derive the following ephemeris for data between 1964 and 2007:

$$JD(max)_{hel} = 2438526.276 + 0.6788049 \times E$$

The phases used in Fig. 1 are derived from this ephemeris. The second set of photographic data (red filled circles) may be slightly shifted in phase with respect to the first set (blue open circles). The shift is equivalent to a period increase of $\sim 0.14 \text{ d Myr}^{-1}$, with an error of the same order (see La Borgne et al. 2007).

3. Revised Chemical Abundances for SDSS J1707+58

The identification of SDSS J1707+58 as an RR Lyrae star requires a revision of the abundance analysis of Aoki et al. (2008). We excluded the spectra obtained at $\phi \sim 0.9$, where the variation with phase of the spectral lines is greatest. We adopted the two spectra with $\phi \sim 0.4$ for analysis. Their total exposure time is 30 minutes; this yields a S/N ratio of 40 per resolution element at 5200 \AA . The effective temperature is estimated from the $(B - V)$ color of 0.43 at this phase (Fig 1b). Allowing for the reddening ($E(B - V) = 0.028$; Schlafly & Finkbeiner 2011), the effective temperature is estimated to be $6100 - 6400 \text{ K}$, using the temperature scales of Alonso et al. (1999) and Casagrande et al. (2010). We adopt 6250 K for the abundance analysis. This is significantly lower than the effective temperature adopted by Aoki et al. (2008), who assumed that the object is a turn-off star.

Our abundance analysis used the ATLAS/NEWODF model atmospheres (Castelli & Kurucz 2003). The microturbulent velocity, v_{mic} , is not well-determined from our analysis of the Fe lines, because the number of the available Fe I lines is small. We assume $v_{\text{mic}} = 3.5 \text{ km s}^{-1}$, with an uncertainty of 1.0 km s^{-1} , taking into account the values assumed in previous studies of very metal-poor RR Lyrae stars: 4.1 km s^{-1} (Preston et al. 2006), 3.0 km s^{-1} (Hansen et al. 2011). We find no significant correlation between the equivalent widths of the Fe I lines and the Fe abundances derived from the individual lines in our analysis, which assumes $v_{\text{mic}} = 3.5 \text{ km s}^{-1}$.

The surface gravity ($g \text{ [cm s}^{-2}\text{]}$) is determined by requiring that the results from the two ionization species Fe I and Fe II agree. Our estimate, $\log g = 2.8$, although uncertain because of the limited number of Fe lines, is a reasonable value for very metal-poor RR Lyrae stars (Hansen et al. 2011).

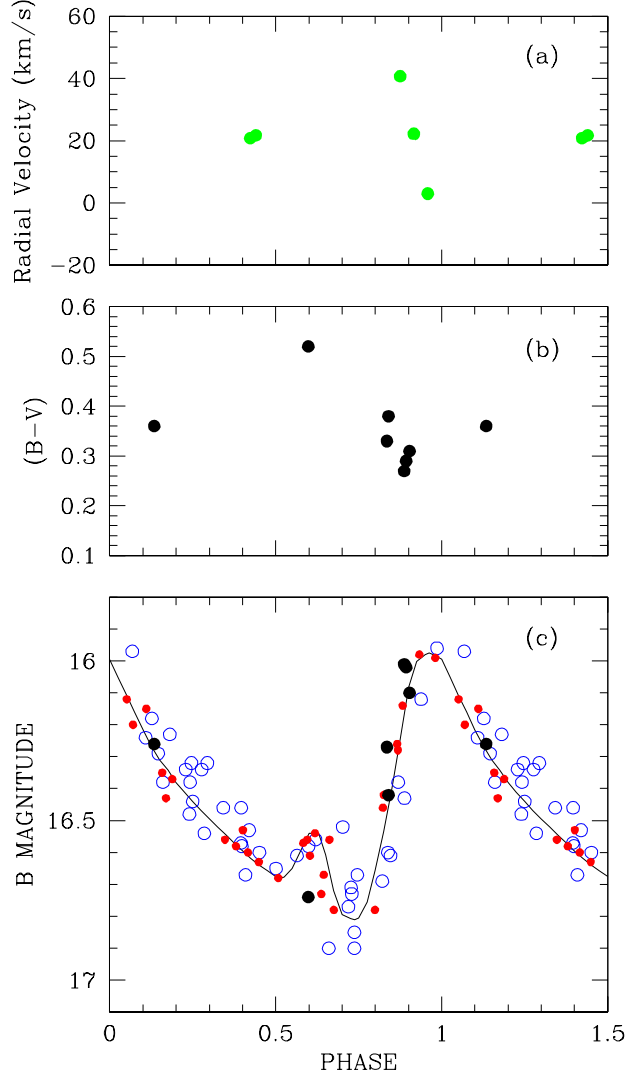


Fig. 1.— (a) Heliocentric radial velocities of SDSS J1707+58, from Table 3 of Aoki et al. (2008), as a function of phase. (b) Photoelectric $(B-V)$ observations of SDSS J1707+58, as a function of phase. (c) B magnitudes of SDSS J1707+58, as a function of phase. The black filled circles are the photoelectric B magnitudes, the red filled symbols are photographic photometry obtained between May 1964 and August 1965, and the blue open circles are photographic photometry obtained between June 1976 and April 1985.

The new abundances are listed in Table 1. The abundance errors are estimated in the same way as by Aoki et al. (2008). Abundance errors caused by uncertainties in the atmospheric parameters are calculated for $\delta(T_{\text{eff}}) = 200$ K, $\delta(\log g) = 0.5$ dex, and $\delta(v_{\text{mic}}) = 1.0$ km s⁻¹. The iron abundance is significantly lower than that found by Aoki et al., (2008), because we adopt a lower T_{eff} and higher v_{mic} in the present analysis. SDSS J1707+58 is one of the most metal (iron)-poor RR Lyrae stars known to date (see Hansen et al. 2011). The C abundance is determined from the CH molecular band at 4323 Å. Although the result is uncertain because of the limited S/N at this wavelength, the large enhancement of C with respect to Fe is remarkable. The excesses of Na, Mg, Sr, and Ba reported by Aoki et al. (2008) are also found in this new analysis. The Ba abundance given by Aoki et al. (2008) is significantly higher than the solar value ([Ba/H] = +0.88); that found in the present analysis is smaller ([Ba/H] = -0.09). The enhancements of C and Ba relative to Fe in SDSS J1707+58 are similar to those found in the CEMP-s stars that have the largest enhancements of these elements.

The excesses of C and Ba that we find for SDSS J1707+58 are much larger than those found by Preston et al. (2006) for the RR Lyrae star TY Gru. These excesses presumably result from the mass transfer from an AGB companion. The referee (G.W. Preston) has pointed out that there is a problem in reconciling how this transfer occurs with the large separation required, because the putative AGB star must have successfully survived RGB evolution without experiencing the consequences of Roche Lobe overflow.

4. The Oosterhoff Types of the Carbon-Enhanced RR Lyrae Stars

The Oosterhoff types of RR Lyraes can be found from their location in the period *vs.* amplitude plot (Fig 2a), and the period *vs.* [Fe/H] plot (Fig 2b). In the former plot, the loci of the Oo I and Oo II stars are shown by solid and dotted lines, respectively (taken from Cacciari et al. 2005). The parallelogram is taken from Fig. 9 of Layden et al. (1999), and is based on the model predictions of RR Lyraes with enhanced helium of Sweigart & Catelan (1998); the RR Lyraes in the metal-rich bulge globular clusters NGC 6388 and NGC 6441 lie within this parallelogram (Pritzl et al. 2000). SDSS J1707+58 (2) lies closer to the Oo II than the Oo I loci, and so is tentatively assigned type Oo II. TY Gru (1) has a variable amplitude (Blazhko effect), so its Oo type is ambiguous on this plot. Both KP Cyg (3) and UY CrB (4) lie outside the loci of other RR Lyrae in globular clusters, and are either not RR Lyrae stars (Andrievsky et al. 2010) or, speculatively, stars with greatly enhanced helium. In Fig 2b, the encircled crosses show the mean periods and [Fe/H] for the RR Lyrae stars in globular clusters: blue symbols for Oo I, red symbols for Oo II, and green symbols for

the clusters (A) NGC 104, (B) NGC 6388, and (C) NGC 6441. SDSS J1707+58 is clearly type Oo II, TY Gru is probably type Oo II, and KP Cyg (3) and UY CrB (4) again have a unique location, as in Fig 2a. From this evidence, we conclude that SDSS J1707+58 is certainly of type Oo II, and TY Gru is probably of type Oo II. The classifications of KP Cyg and UY CrB are ambiguous, and in investigating their kinematics below, we consider absolute magnitudes appropriate for both RR Lyrae stars ($M_v = +0.5$) and BL Her stars ($M_v = -0.25$).

5. The Kinematics of Carbon-Enhanced RR Lyrae Stars

The M_v of SDSS J1707+58 and TY Gru were taken to be +0.24 and +0.45, respectively. We assumed $[\text{Fe}/\text{H}] = -2.92$ for SDSS J1707+58 and $[\text{Fe}/\text{H}] = -1.91$ for TY Gru (For et al. 2011), and derived the M_v from the following expression, given by Clementini et al. (2003):

$$M_v = 0.214[\text{Fe}/\text{H}] + 0.86$$

The interstellar extinction $E(B - V)$ for SDSS J1707+58, TY Gru, and UY Cyg was taken from Schlafly & Finkbeiner (2011), but not for KP Cyg, which has too low a Galactic latitude for this method to be valid. KP Cyg is 66 arcsec from the 7th magnitude star HD 190916, for which Appenzeller (1996) gave $E(B - V) = 0.45$, and a distance of 3.5 kpc. We assumed an $E(B - V)$ of 0.32 for KP Cyg, and derived an intensity-weighted mean V magnitude for this star of 12.81 from the light-curve of Schmidt (2002); this yields distances of 1.83 kpc and 2.59 kpc for $M_v = +0.50$ and -0.25 , respectively. Mean intensity-weighted V magnitudes of 15.96, 14.12, and 12.76 were derived from the light curves of SDSS J1707+58, TY Gru, and UY Cyg (this paper; Preston et al. 2006; Schmidt 2002, respectively). These yield distances of 13.39 kpc and 5.32 kpc for SDSS J1707+58 and TY Gru, respectively. The distance to UY Cyg is 2.70 kpc if it is an RR Lyrae star, and 3.81 kpc if it is a BL Her star. Mean radial velocities of TY Gru and KP Cyg were derived from the velocities given in Preston et al. (2006) and Andrievsky et al. (2010), respectively. The accuracies of the γ -velocities of KP Cyg, and to a lesser extent UY CrB, are limited by uncertainties in their ephemerides; nevertheless, their errors should not exceed $\pm 5 \text{ km s}^{-1}$. A mean velocity of -39.7 km s^{-1} was determined for UY CrB from three spectra obtained with the FLWO 1.5-m telescope, using the FAST spectrograph with a 600 l/mm grating and a 2 arcsec slit. This yielded 2.0 Å resolution, with a spectral coverage from 5500 – 7550 Å. Our exposures resulted in a S/N of 100 per resolution element in the continuum. The heliocentric space velocities U , V , and W were derived from the proper motions, radial velocities, and distances using the program of Johnson & Soderblom (1987). These results are summarized in Table 2. TY Gru and SDSS J1707+58 are halo stars that very probably have prograde rotations, and so are likely

Table 1. The Chemical Composition of SDSS J1707+58

Element (Species)	$\log \epsilon$	[X/Fe]	N	σ
C (CH)	8.30	2.79	1	0.41
Na (Na I)	5.72	2.40	2	0.28
Mg (Mg I)	5.80	1.12	2	0.27
Ca (Ca I)	4.36	0.94	2	0.14
Ti (Ti II)	2.70	0.67	3	0.19
Fe (Fe I)	4.58	-2.92^a	5	0.18
Fe (Fe II)	4.58	-2.92^a	2	0.20
Sr (Sr II)	0.70	0.75	2	0.65
Ba (Ba II)	2.09	2.83	5	0.51

^a[Fe/H] values.

Table 2. Data for carbon-enhanced RR Lyrae stars.

Star	Type ^a	Period days	Z ^b kpc	[Fe/H]	[C/Fe]	[Ba/Fe]	U ^c km s ⁻¹	V ^c km s ⁻¹	W ^c km s ⁻¹	Notes
SDSS 1707+58	RRab	0.678	7.59	-2.92	+2.79	+2.83	-224±191	-112±114	+195±154	1,A
TY Gru	RRab	0.570	4.42	-2.00	+0.89	+1.23	-075±028	-111±032	-043±019	2,B
KP Cyg	RRab	0.856	0.13	+0.18	+0.52	...	+016±017	+013±006	+010±023	3,B
KP Cyg	CWB	0.856	0.18	+0.18	+0.52		+021±024	+012±008	+014±033	3,B
UY CrB	RRab	0.929	1.96	-0.40	+0.65	...	+032±021	-051±020	-041±015	3,B
UY CrB	CWB	0.929	2.76	-0.40	+0.65		+053±031	-063±029	-046±021	3,B

Notes to Table 2:

- (1) Data from this paper. (2) Type, Period, and abundances from Preston et al. (2006). (3) Type and abundances from Wallerstein et al. (2009). (A) Proper motions from the SDSS DR8 Catalog (Adelman-McCarthy et. al. 2011). (B) Proper motions from the UCAC3 Catalogue (Zacharias et al. 2010).

^aCWB = BL Her type Cepheid.

^bHeight above Galactic plane in kpc.

^cHeliocentric space velocities U , V , and W .

Table 3. Candidates for Carbon-Enhanced RR Lyrae Stars

Star	R.A. ^a	Dec. ^a	V ^b (mag)	Period (days)	V -amp. ^c (mag)	$\Delta \log P$ ^d	$ Z $ ^e (kpc)	R_{gal} ^f (kpc)	$[C/Fe]$ ^g	Notes
VX Scl	023.°8486	−35.°1285	12.00	0.6373	0.83	+0.0344	2.0	08.4	+1.8	1
BE Eri	069.°5145	−01.°9958	13.04	0.5796	1.00	+0.0191	1.6	10.8	+2.4	2
U Lep	074.°0749	−21.°2172	10.58	0.5815	1.10	+0.0498	0.6	08.7	+0.2	1
IV Leo	164.°5523	−00.°0945	15.72	0.6358	0.42	+0.0108	8.5	14.7	+0.2	3
LM Leo	172.°9572	−02.°2405	15.51	0.6762	1.04	+0.0930	8.3	13.1	+3.5	3
LO Leo	173.°8448	−00.°8952	15.47	0.6070	1.12	+0.0606	8.0	12.7	+1.1	3
LP Leo	174.°1658	−01.°4213	16.77	0.6492	0.56	−0.0122	15.1	20.0	−0.4	3
v370 Vir	181.°5172	−02.°2159	15.23	0.6993	0.89	+0.0833	7.5	11.3	+1.7	3
v408 Vir	190.°0147	−00.°0693	16.99	0.5859	0.70	−0.0177	17.9	20.0	+0.7	3
1245-04	191.°2627	−04.°3197	16.10	0.7460	0.36	+0.0535	11.2	13.4	+2.4	4
ZZ Vir	200.°9110	−04.°3617	14.27	0.6841	0.89	+0.0736	4.6	07.6	+0.9	1
WY Vir	203.°8173	−06.°9730	13.44	0.6094	1.11	+0.0603	3.4	07.0	+3.9	1
1453-11	223.°4947	−11.°8973	15.61	0.7496	0.42	+0.0605	6.3	06.1	+4.5	4
1529-05	232.°4714	−05.°8573	15.74	0.7343	0.46	+0.0554	6.5	05.9	+2.2	4
2212-16	333.°0472	−16.°5797	16.27	0.6969	0.55	+0.0420	11.3	12.5	+3.4	4
2343+01	355.°8220	+01.°1742	13.04	0.6007	0.60	+0.0184	16.6	21.2	−0.4	4

Notes to Table 3:

- (1) Photometry from Kinemuchi et al. (2006). (2) Photometry from Schmidt & Seth (1996).
(3) Photometry from Vivas et al. (2004). (4) Photometry from Miceli et al. (2008).

^aEpoch J2000.

^bApparent visual magnitude.

^cAmplitude of V magnitude.

^dShift in log Period from locus of Oo I stars in log Period *vs* Amplitude plot.

^eDistance from Galactic plane in kpc.

^fGalactocentric distance in kpc.

^gAbundances from Christlieb et al. (2008).

to belong to the inner-halo population. KP Cyg and UY CrB are clearly disk objects.

6. Future work

Following Carollo et al. (2012), new CEMP RR Lyrae stars are likely to be found among stars of low metallicity that are far from the Galactic plane. Christlieb et al. (2008) give $[C/Fe]$ approximate abundance ratios for metal-poor stars found in the Hamburg/ESO objective prism survey. We have searched this survey for RR Lyrae stars with periods greater than 0.57 days in (a) the QUEST RR Lyrae Survey (Vivas et al. 2004), (b) the LONEOS RR Lyrae Survey (Miceli et al. 2008), and (c) the survey of RR Lyrae stars by Wils & Christopher (2006). We also included local RR Lyrae stars with $[Fe/H] \leq -2.0$ that are listed by Layden (1994). Sixteen RR Lyrae stars were found in the Christlieb et al. (2008) catalog; they are listed in Table 3. Twelve of these have $[C/Fe] \geq +0.7$, and ten have $[C/Fe] \geq +1.0$. We call these stars “candidates,” because their abundance ratios were derived from low-resolution objective-prism spectra. For each candidate, Table 3 gives the shift $\Delta \log$ period between the log period of the star and that of an Oo I star of the same V amplitude. The six candidates with $[C/Fe] < +1.0$ have a mean shift of $+0.016 \pm 0.018$, which shows that they are Oo I stars, whereas the ten candidates with $[C/Fe] > +1.0$ have a mean shift of $+0.056 \pm 0.007$. Thus the candidates with $[C/Fe] > +1.0$ primarily belong to the Oo II class (which tend to be more metal-poor than those of the Oo I class). It is desirable that the abundances in these stars should be determined from high-resolution spectra, and that a more extensive search for carbon-enhanced RR Lyrae stars should be made along the lines outlined above (new searches of the HES prism plates for additional CEMP stars, including possible RR Lyraes, are already underway; Placco et al. 2011).

7. Summary

We show that the CEMP-s star SDSS J1707+58 (studied by Aoki et al. 2008) is the same as the RR Lyrae star VIII-14 (Suntzeff et al. 1991). We give revised abundances for the star of $[Fe/H] = -2.92$, $[C/Fe] = +2.79$, and $[Ba/Fe] = +2.83$; it is thus one of the most metal-poor RR Lyrae known, and together with TY Gru (Preston et al. 2006), one of only two RR Lyrae stars known to have CEMP-s properties. Both SDSS J1707+58 and TY Gru are Oo II halo stars with prograde orbits. They differ from the mildly carbon-enhanced stars KP Cyg and UY CrB, which are disk stars, and whose variable type is ambiguous. Wallerstein & Huang (2010) derived $[C/Fe]$ for 24 RR Lyrae stars with $-2.68 \leq [Fe/H] \leq +0.24$, and concluded that high $[C/Fe]$ went with metal-rich stars. We, following Carollo et

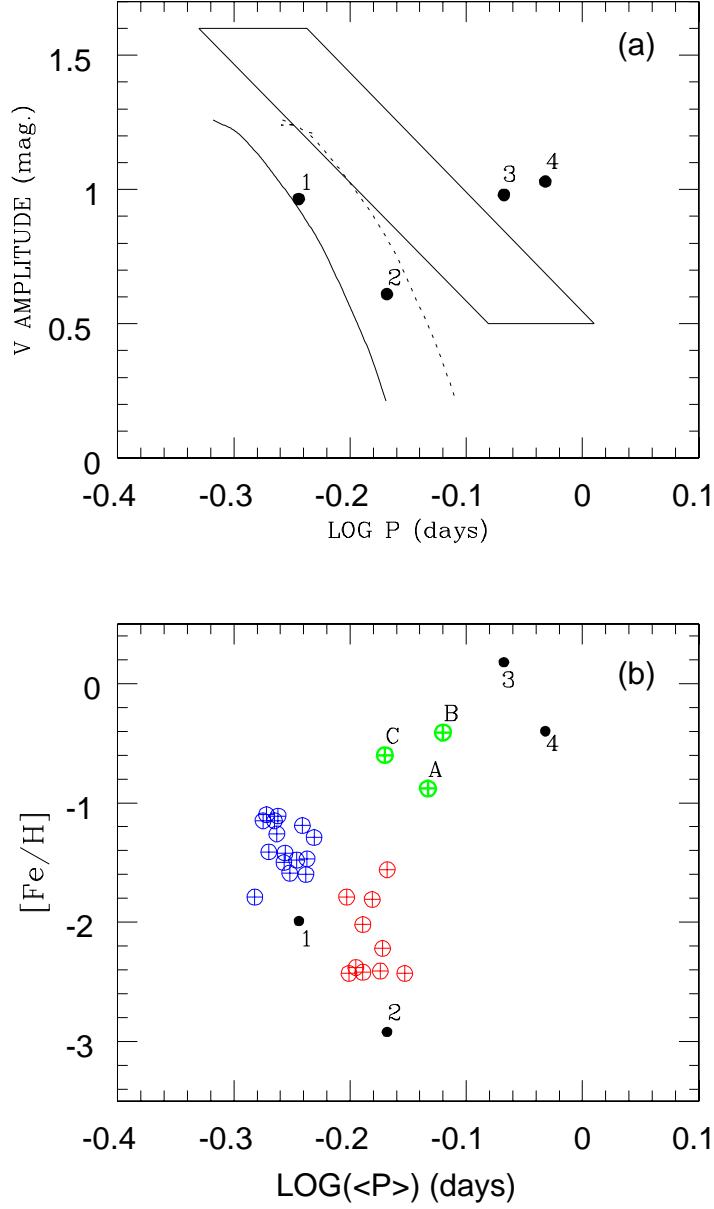


Fig. 2.— (a) The ordinate is V amplitude; the abscissa is log period (days). (b) The ordinate is metallicity $[\text{Fe}/\text{H}]$; the abscissa is log mean period (days) for RR Lyraes in globular clusters. Periods are from Bono et al. (2007) and $[\text{Fe}/\text{H}]$ are from Kraft & Ivans (2000). For further details, see text.

al. (2012) and others cited in the text, find that high $[C/Fe]$ ratios are also often associated with metal-poor RR Lyrae stars. In support of this, we provide a list of 16 RR Lyrae stars that are found in the catalogue of metal-poor stars of Christlieb et al. (2008); ten of these stars have $[C/Fe] > +1.0$, and have the characteristics of Oo type II variables. It is important that these stars be observed at higher spectral resolution in order to confirm their abundances.

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